

# Nuclear effects of $\varphi$ -meson Production

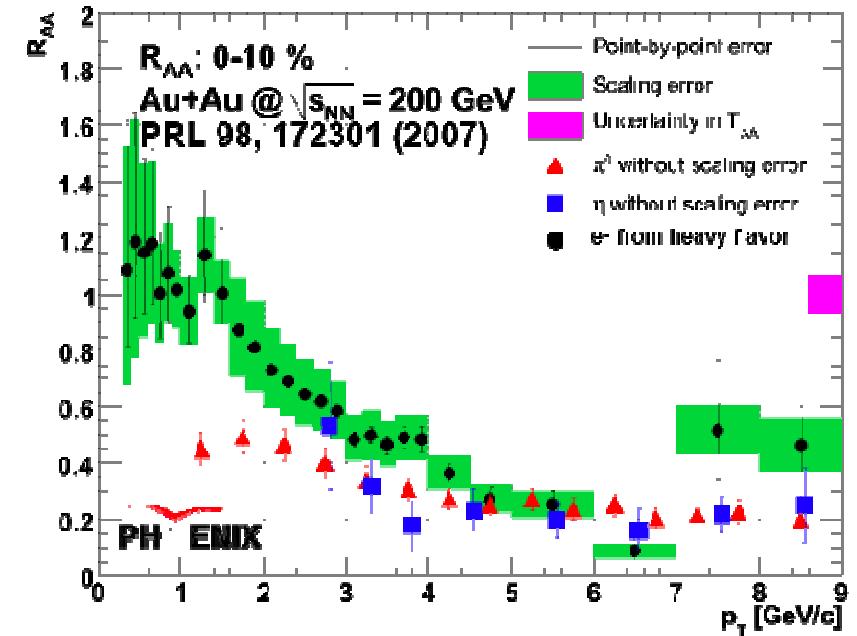
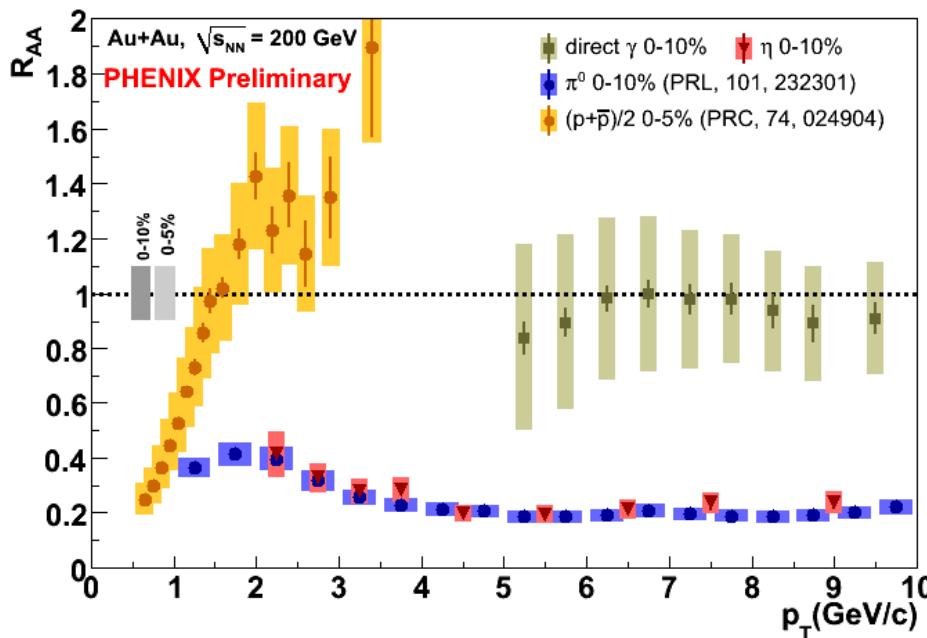


**Julia Velkovska**



**RHIC/AGS User Meeting  
Workshop on Hydro and Initial  
Conditions**

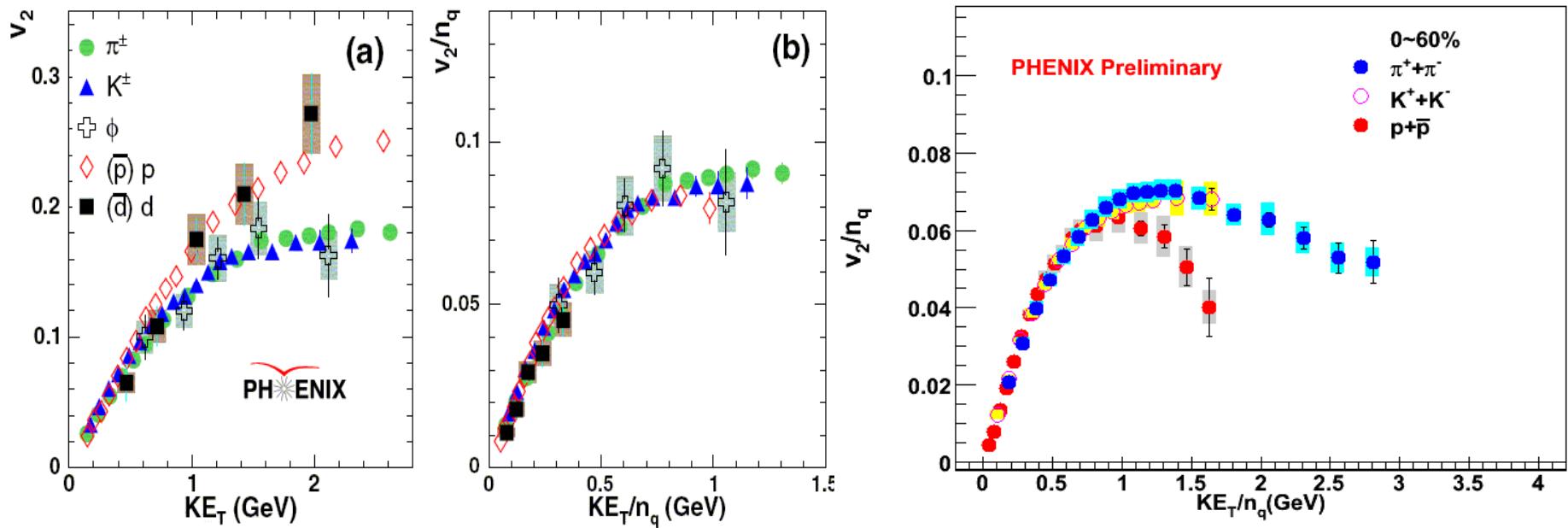
# Motivation for $\varphi$ -meson studies: particles species dependent suppression



- Baryon/meson difference at intermediate  $p_T$ 
  - $m_\varphi \approx m_p$  - test mass vs quark # content
- Same suppression for light and heavy quarks  $> p_T \sim 5$  GeV/c
  - $\varphi$ -meson with sufficient  $p_T$  reach can test quark mass dependence

# Motivation for $\varphi$ -meson studies: quark number scaling in elliptic flow

Phys. Rev. Lett. 99, 052301 (2007)

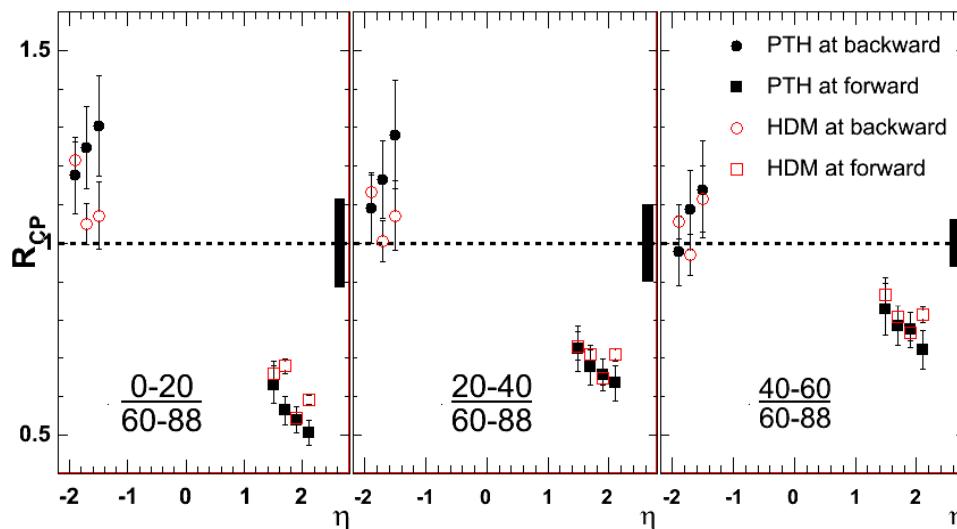


- Elliptic flow ( $\varphi$  included) scales with quark number for  $KE_T/n_q \leq 1$  GeV
- Protons decouple at  $KE_T/n_q \approx 1$  GeV
- How does  $\varphi$  behave at high  $p_T$ ?

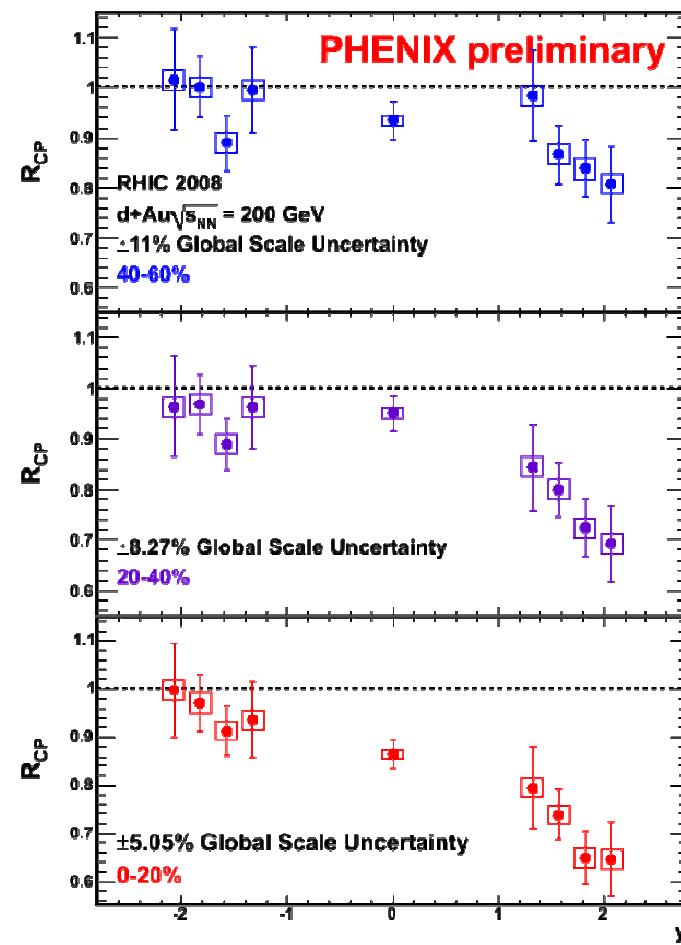
# Motivation for $\varphi$ -meson studies

## CGC and cold nuclear matter effects

Phys. Rev. Lett. 94, 082302 (2005)



- Hadron production in d+Au away from mid-rapidity
  - Initial vs Final state hadron suppression
  - Cold Nuclear Matter Effects on J/ $\psi$
- Low Mass Vector Meson studies can add new aspects due to the study of different production mechanism and hadronic interactions



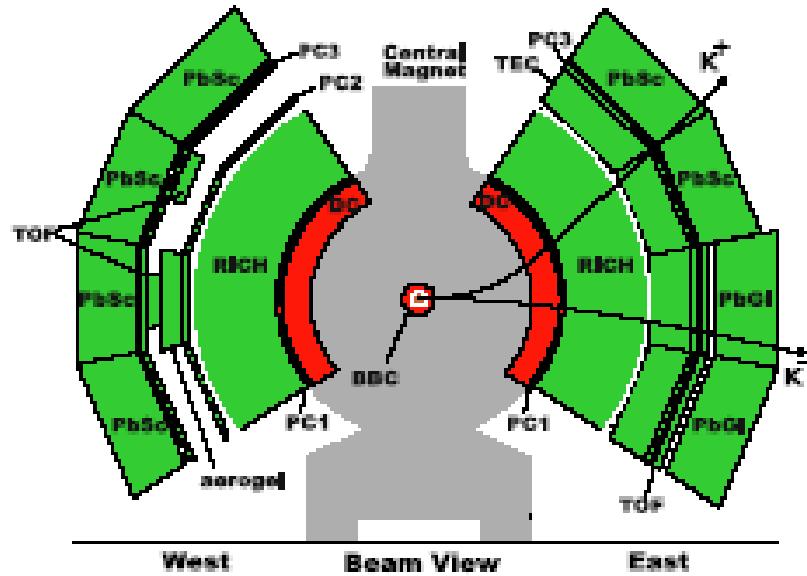
# Outline of results

- Mid-rapidity spectra and nuclear modification factors of  $\phi \rightarrow K^+ K^-$ 
  - p+p (Run 5), d+Au (Run 8), Au+Au (Run 4) and Cu+Cu (Run 5) @ 200 GeV
  - arXiv:1004.3532v2 [nucl-ex] Submitted to PRC
  - Poster by M. Naglis and D. Kotov at this meeting
- Mid-rapidity  $v_2$  of  $\phi \rightarrow K^+ K^-$  (Run7, Preliminary)
- Forward and backward rapidity  $\phi \rightarrow \mu^+ \mu^-$  in d+Au @ 200 GeV (Run 8, Preliminary)

# Mid-rapidity spectra and $R_{AA}$

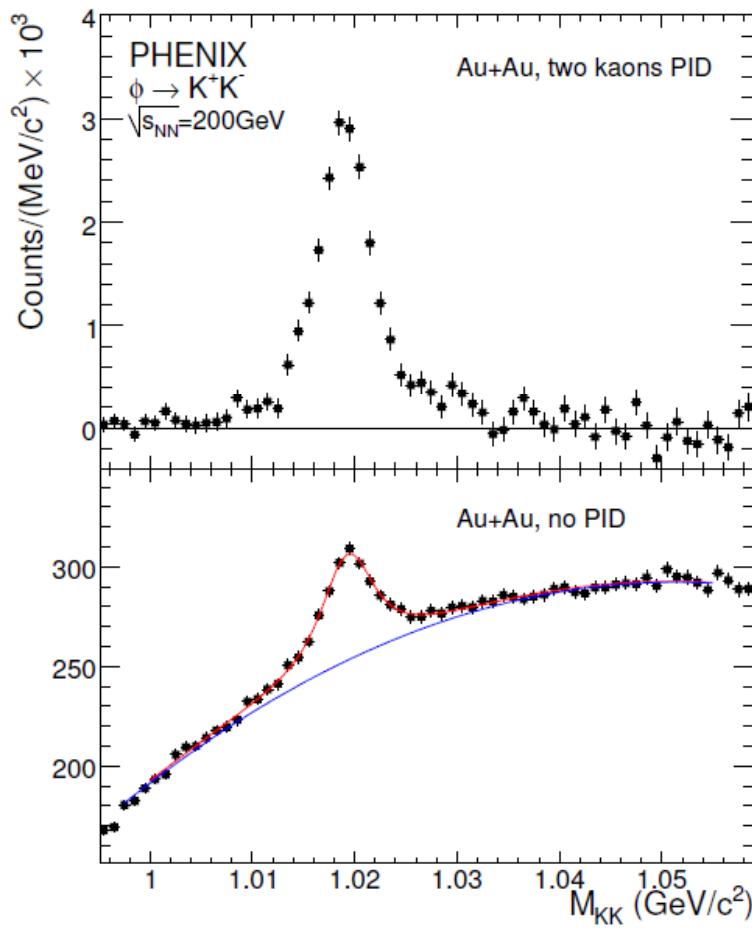
# Experimental techniques

Acceptance:  $-0.35 < \eta < 0.35$ ,  $2 \times 90^\circ$  in  $\varphi$



- Trigger: minimum bias
- Tracking:
  - DC/PC1
  - Track matching to PC3
- Kaon ID : TOF.E
  - $\sigma_t \sim 115$  ps
  - $\pi/K$  separation  $0.3 < p_T < 2.5$  GeV/c
- 3 methods of  $\varphi$  reconstruction
  - 2 kaon PID
  - 1 kaon PID
  - No PID

# Signal extraction

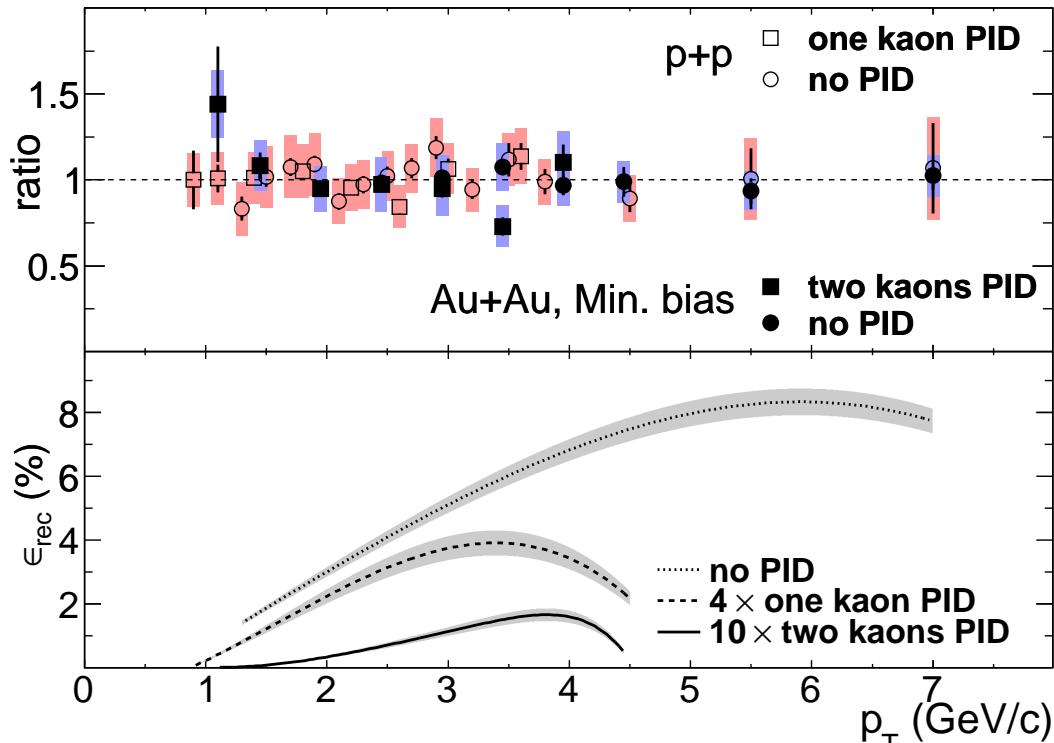


- Subtract the combinatorial BG from event mixing
- Subtract any residual BG
- Integrate  $M_{\text{inv}}$  in  $\pm 9 \text{ MeV}$  around the peak

‘no-PID’ fit with Breit-Wigner + Gaussian + polynomial

Systematic errors on yield 6-25%

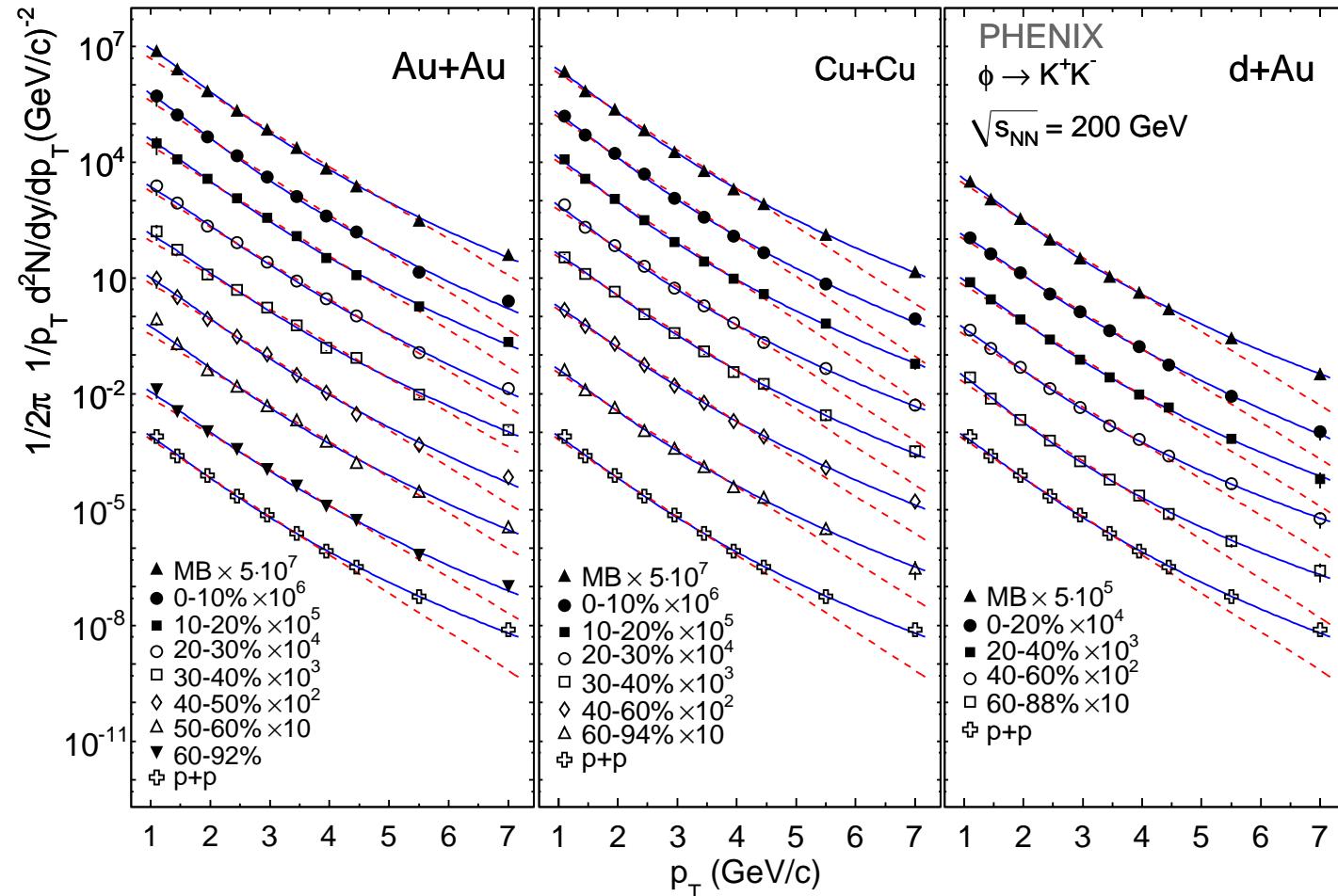
# Acceptance, efficiency, $p_T$ reach, S/B



Species	$N [10^9]$	$p_T$ [GeV/c]	S/B	Technique
$p+p$	1.50	0.9–4.5	1/9 - 1/2	"one kaon PID"
	1.44	1.3–7.0	1/76 - 1/3	"no PID"
$d+Au$	1.69	1.1–7.0	1/245 - 1/12	"no PID"
	0.77	1.1–2.95	1/91 - 1/9	"one kaon PID"
$Cu+Cu$	0.78	1.9–7.0	1/205 - 1/24	"no PID"
	0.72	1.1–3.95	1/19 - 1/2	"two kaons PID"
$Au+Au$	0.82	2.45–7.0	1/385 - 1/32	"no PID"

- Significant improvement in acceptance and  $p_T$  reach with no-PID
- Systematic check with 2-kaon PID

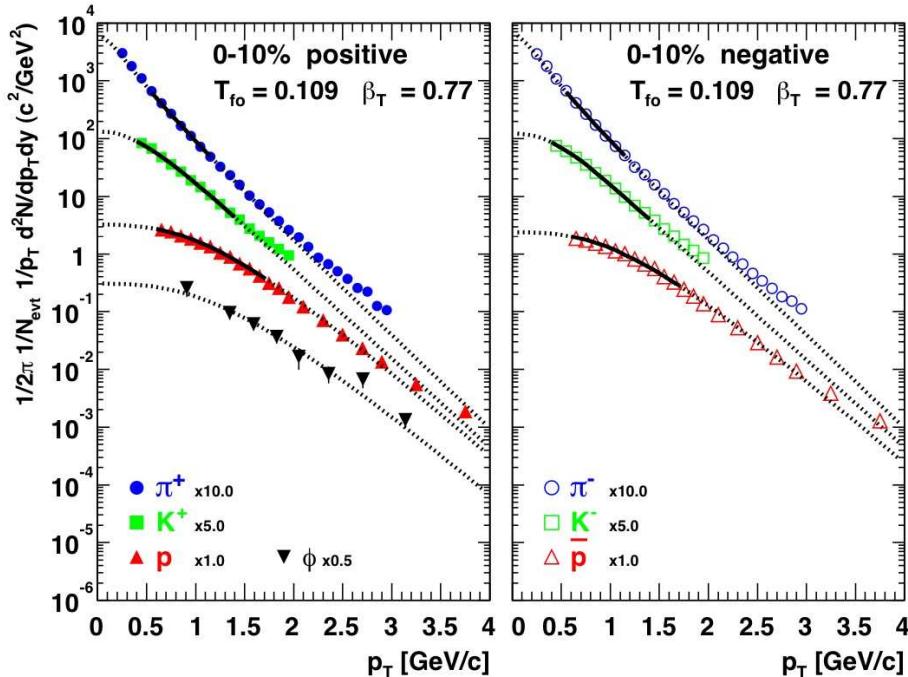
# $\Phi$ Spectra in AuAu, CuCu, dAu, pp



- Spectra well described by Levy distribution
- Deviation from exponential for  $p_T > 5 \text{ GeV}$

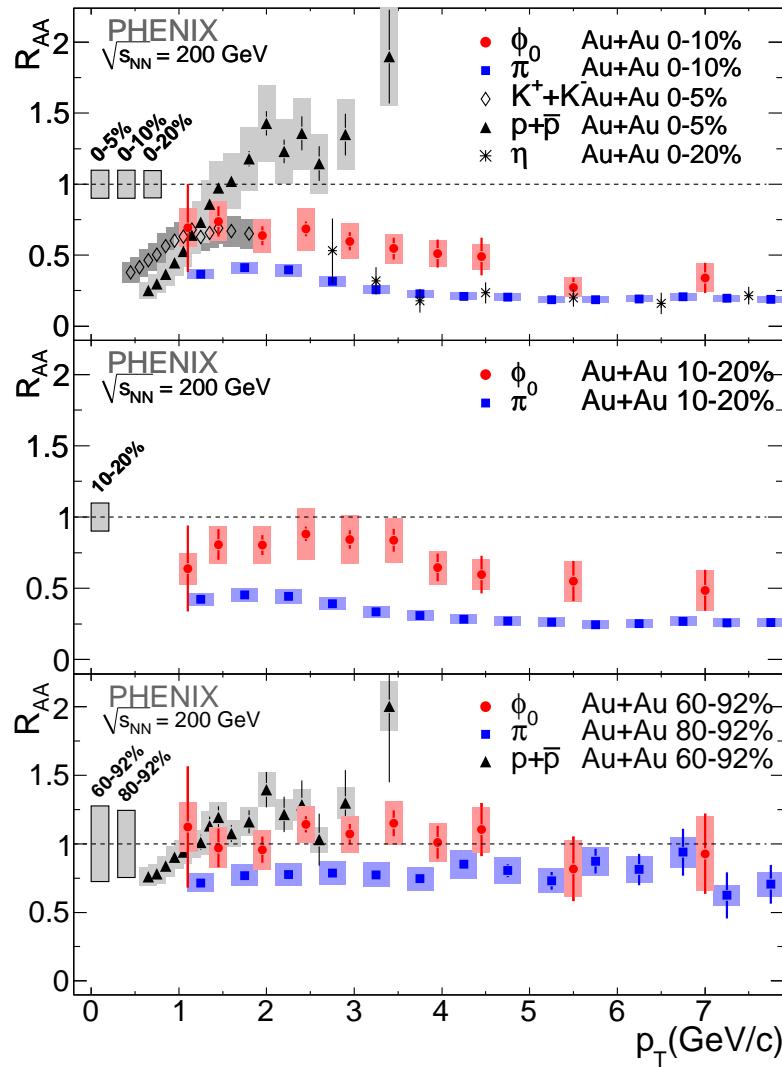
# Does $\varphi$ participate in radial flow ?

Run 2 Phys. Rev. C 72, 014903 (2005)



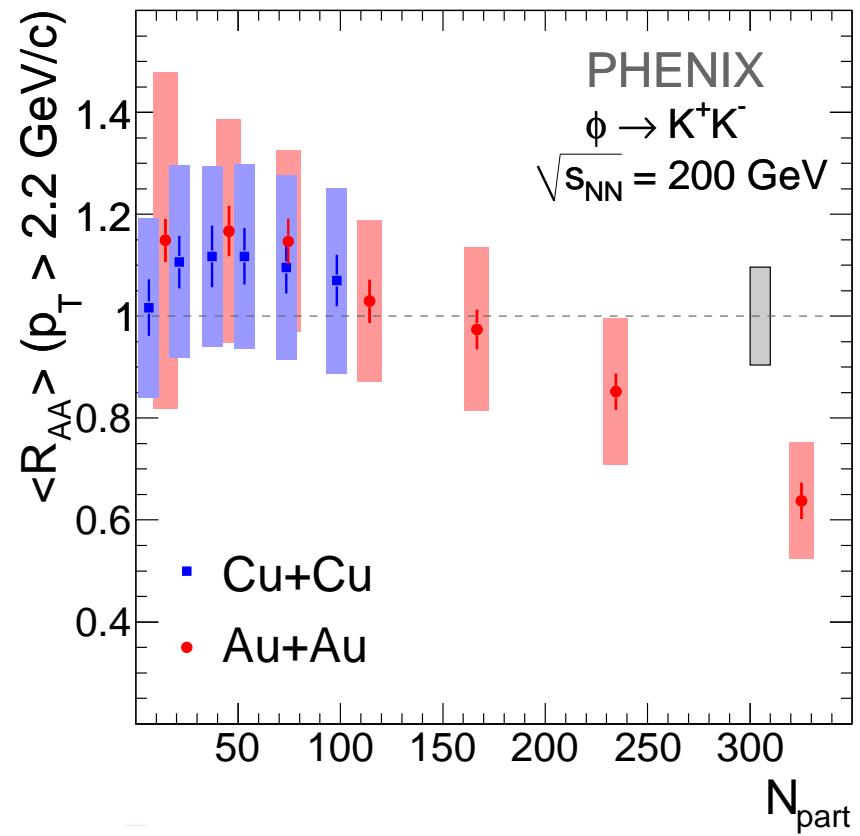
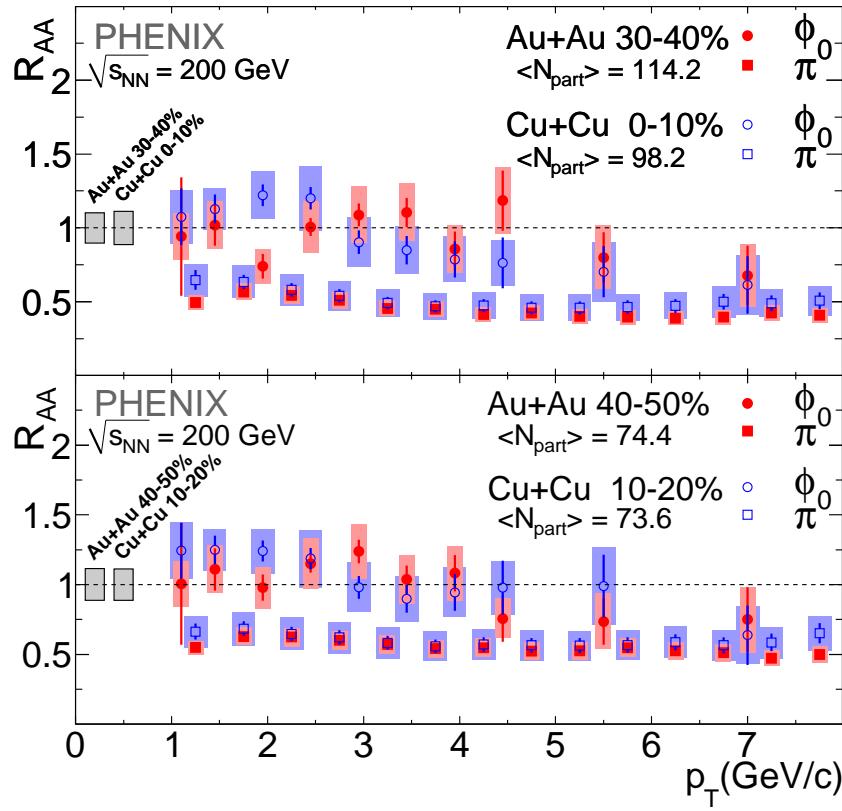
- Run 2 result
  - $\Phi$  can be described with the same blast-wave parameters as  $\pi, K, p$
- Run 2 and Run 4 spectra are consistent within errors
- Not sufficient low  $p_T$  reach for discriminative power

# Nuclear Modification Factors in AuAu



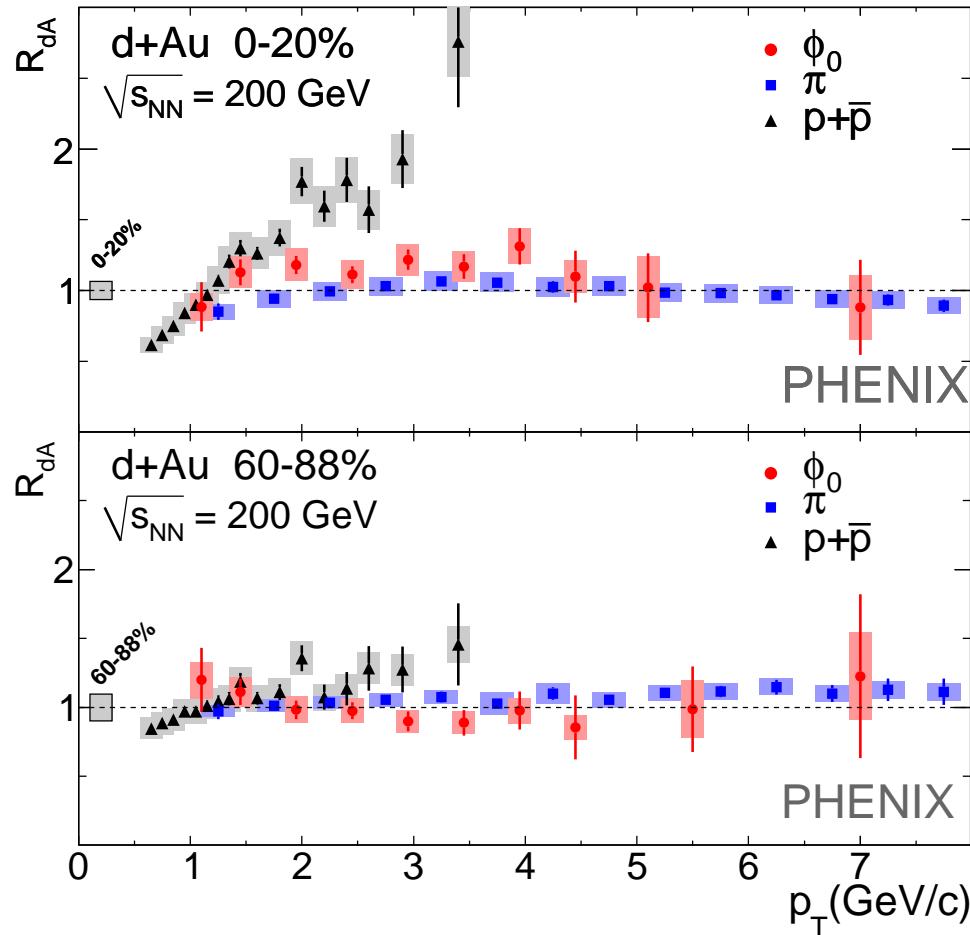
- $\Phi$  is suppressed in central collisions
  - $R_{AA}^\pi < R_{AA}^\phi < R_{AA}^p$
  - At high  $p_T > 5$  GeV/c  $R_{AA}^\phi \sim R_{AA}^\pi$
  - discrepancy with STAR result
  
- Suppression is centrality dependent
  
- No  $\phi$  suppression in peripheral collisions
- Differences between hadrons persist for all centralities

# $R_{AA}$ in Cu+Cu and Au+Au



- In Cu+Cu difference in  $R_{AA}$  of  $\phi$  and  $\pi$  remains
- Suppression depends on  $N_{\text{part}}$  not on collision system

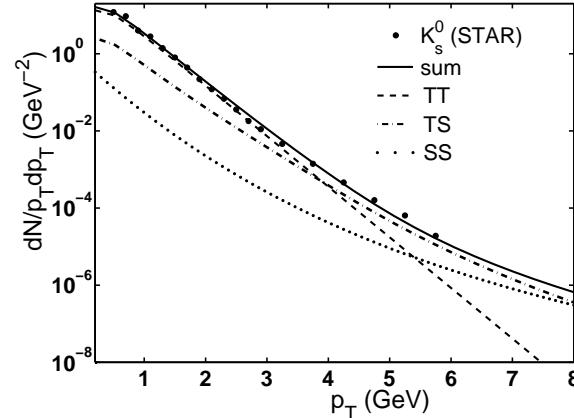
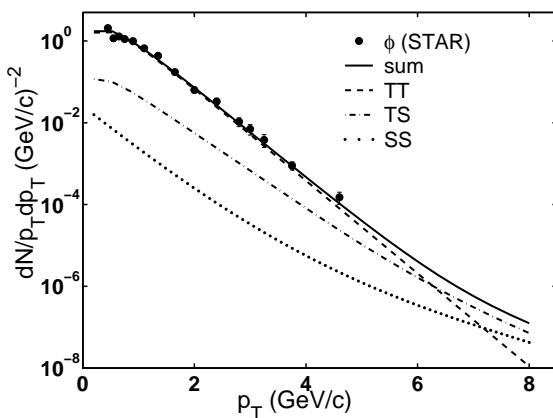
# $R_{dA}$ : test of initial state effects



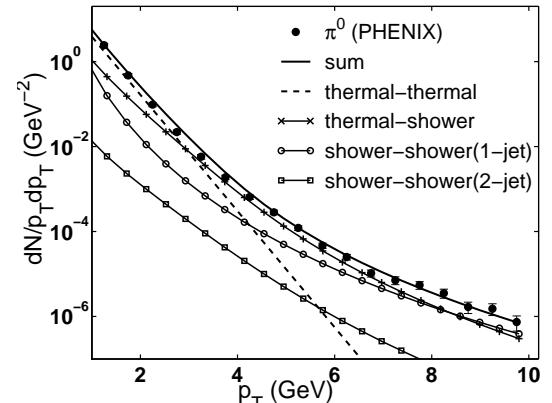
- Central collisions:
  - $R_{dA}^\varphi < R_{dA}^p$
  - $R_{dA}^\varphi \sim R_{dA}^\pi$
  - Strong Cronin enhancement for protons => not a mass effect
- Similar behavior for all hadrons in peripheral collisions
- Initial state effects do not explain the different suppression of  $\varphi$  and  $\pi$  in AA

# Is recombination the answer ?

Hwa, Yang arXiv:nucl-th/0602024v3

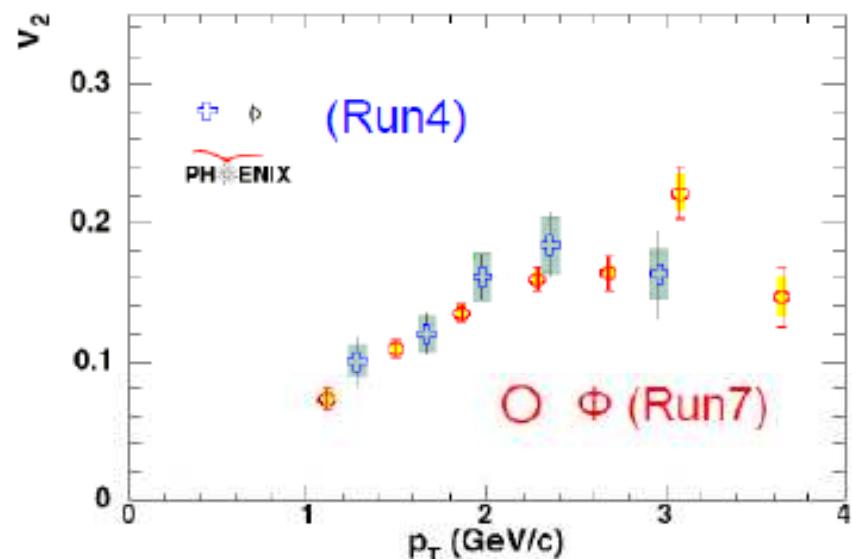
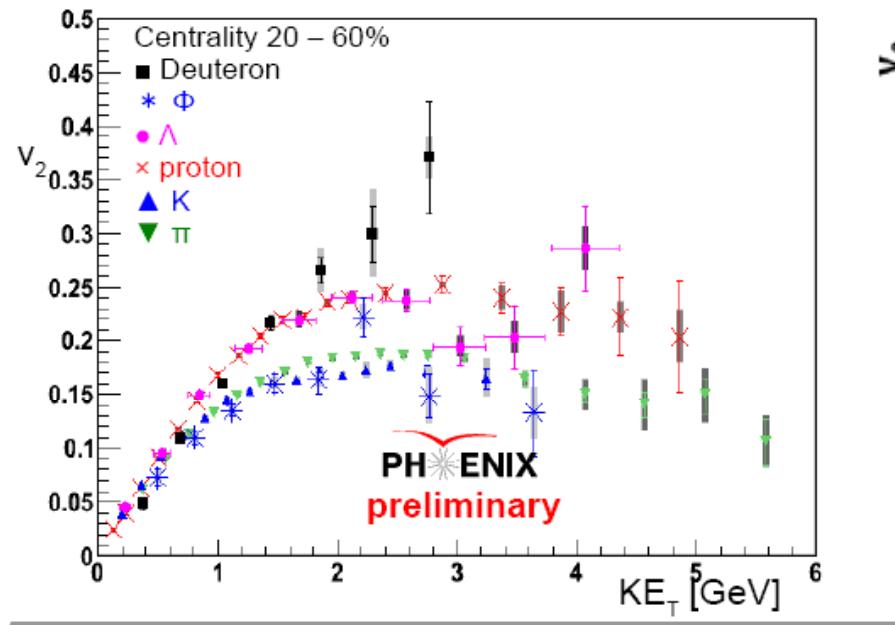


J.Phys. G30 (2004) S1117-S1120



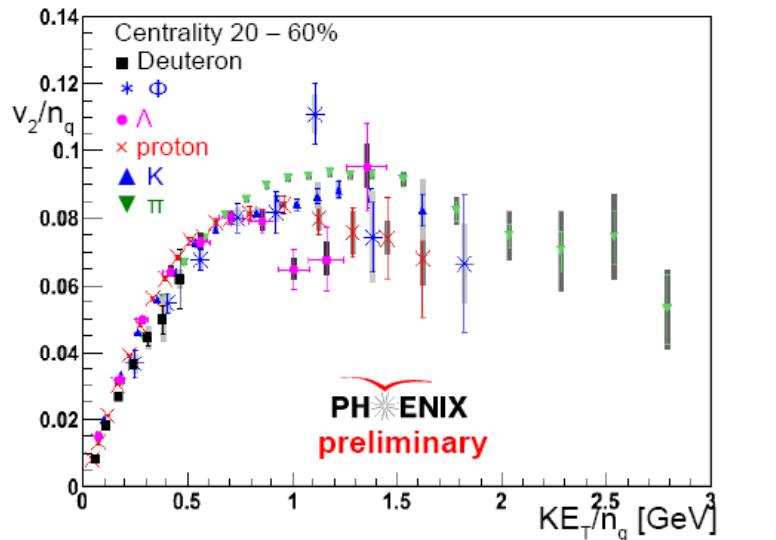
- TT dominates to higher for  $p_T$  for  $\phi$  in comparison to  $\pi$
- T distribution fit to reproduce  $K_0$  data
- Normalization of  $\phi$  spectra is a free parameter “to account for the medium effect on the recombination of s and sbar”
- Only spectral shape comparison can be done with RECO,  $R_{AA}$  is not a prediction

# Recent results on high-pt identified hadron v2



- Extended  $p_T$  range for identified hadron  $v_2$  measurement form Run 7 and with the use of TOF.W PID

# Testing quark number scaling of $\varphi v_2$



- Breaking should occur at the transition between TT and TS recombination
- This point should be different for  $\Phi, p, \pi$
- Late hadronic rescattering may be also different
- Error bars in  $\Phi$  data too big to judge
- Phenix will be able to study QNS breaking for more hadron species with Run 10 data



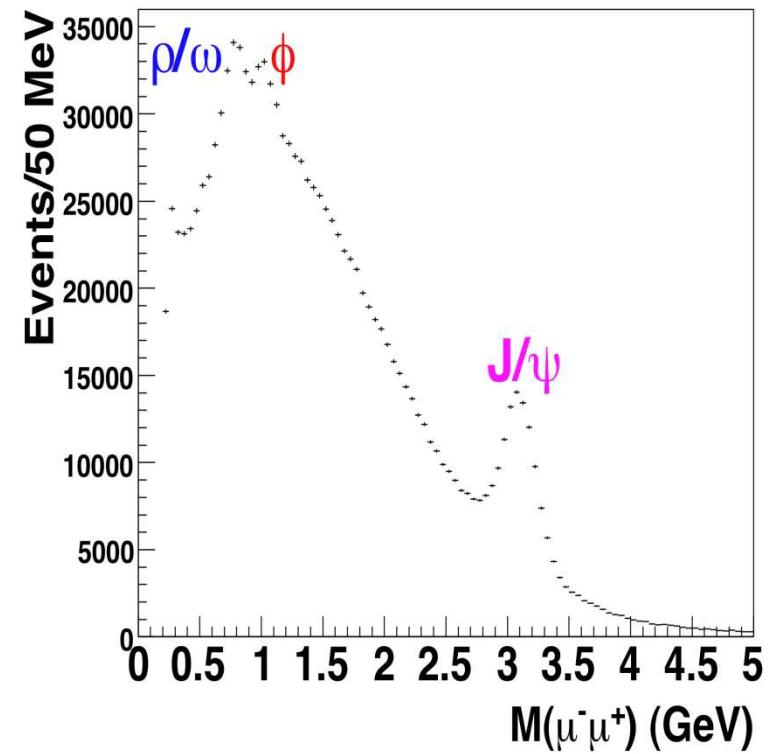
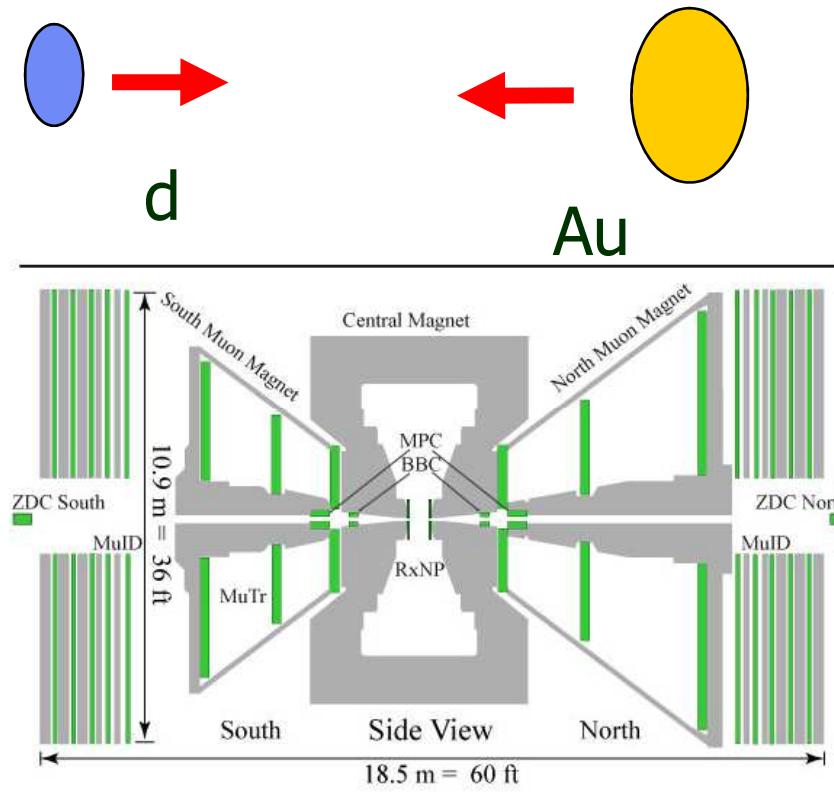
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Looking forward

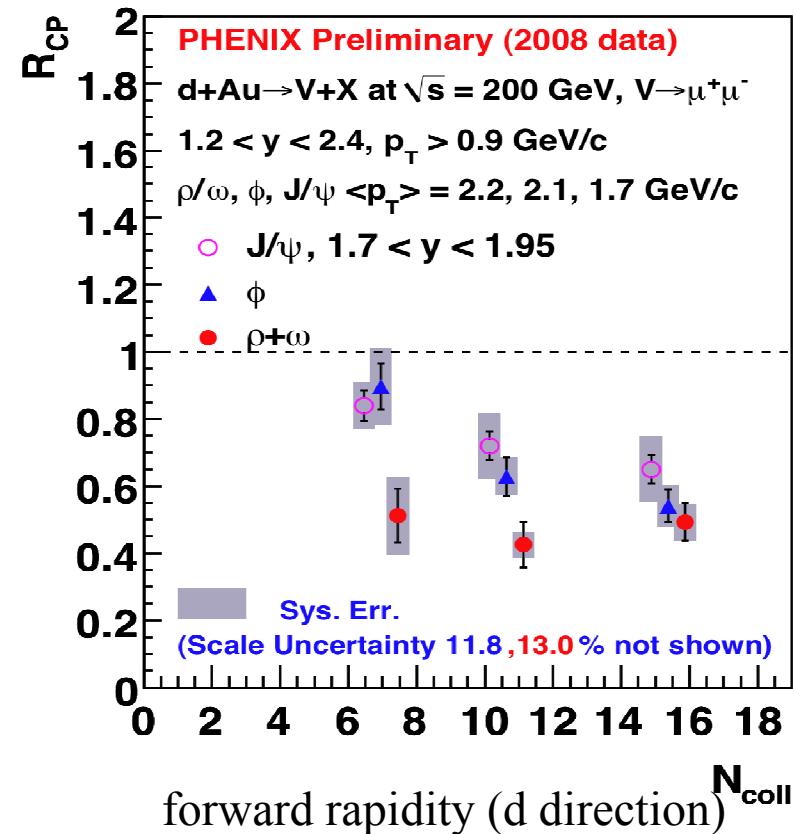
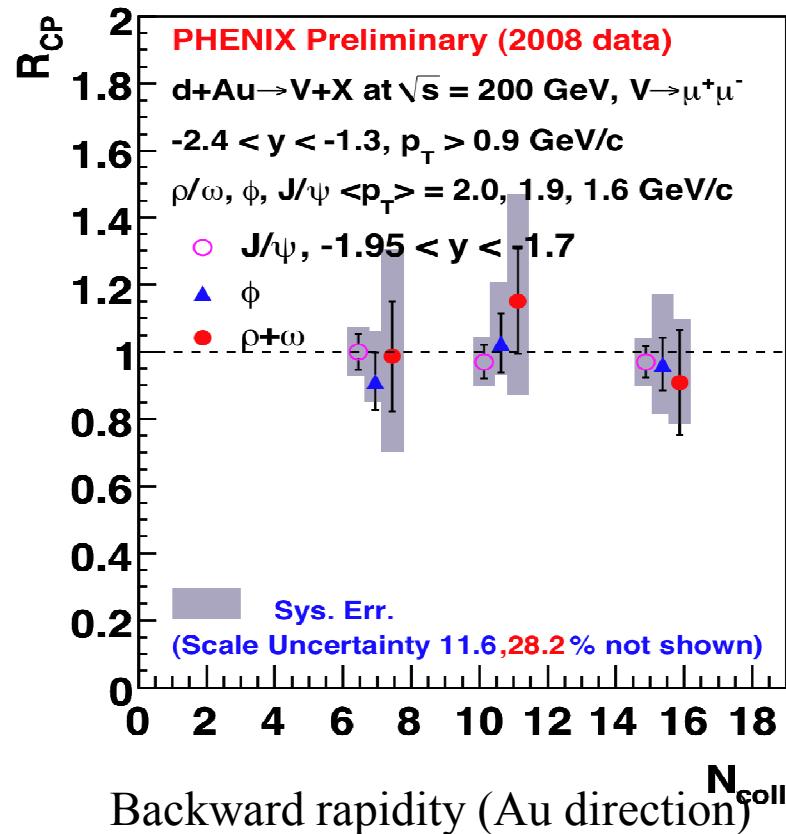
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in rapidity

# Measurements of light vector mesons in d+Au using $\mu^+\mu^-$ decays



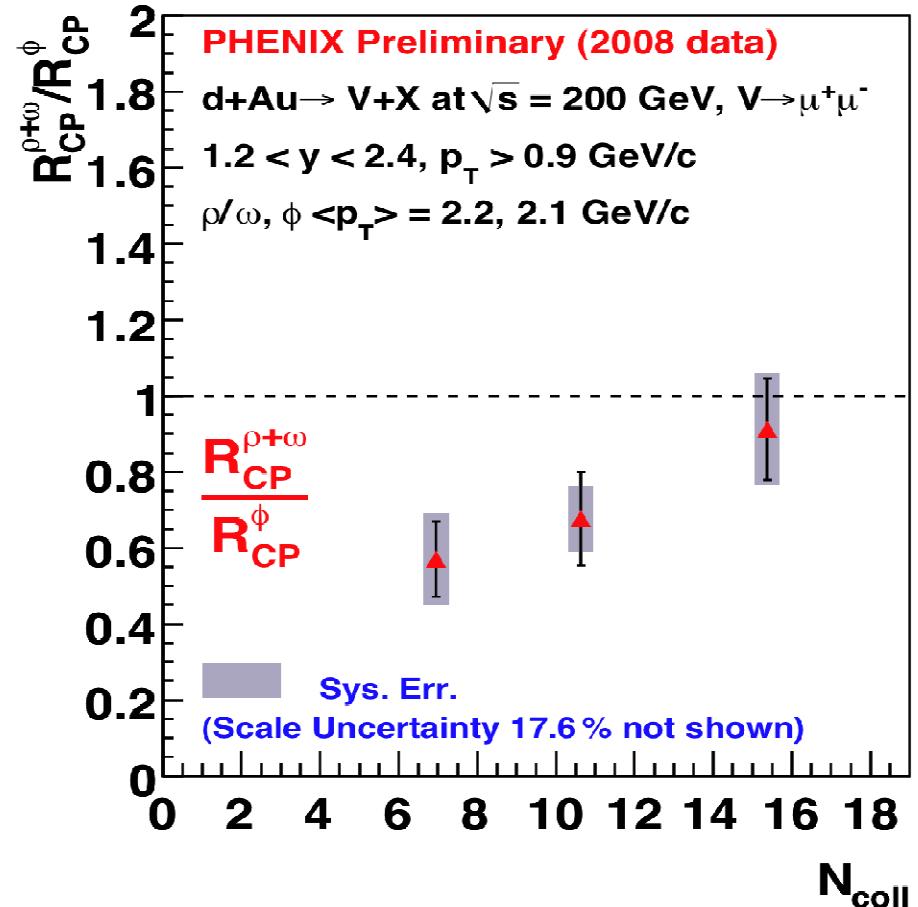
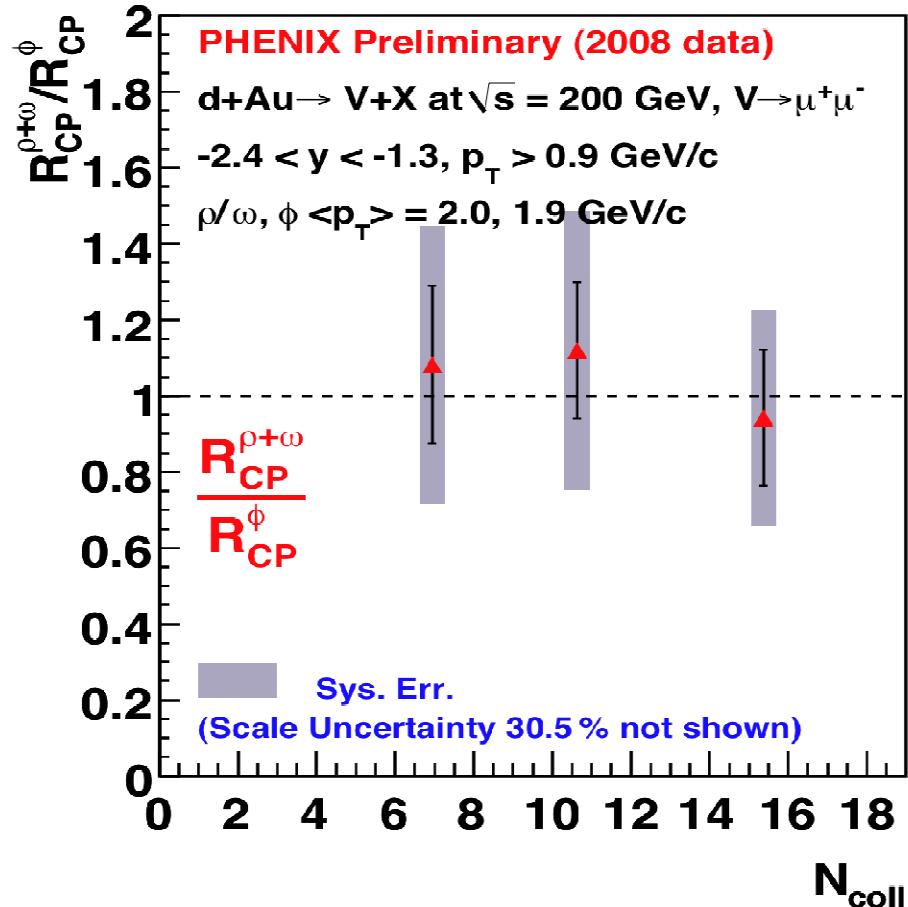
# $R_{cp}$ of $\rho+\omega$ , $\phi$ and $J/\psi$



Lei Guo

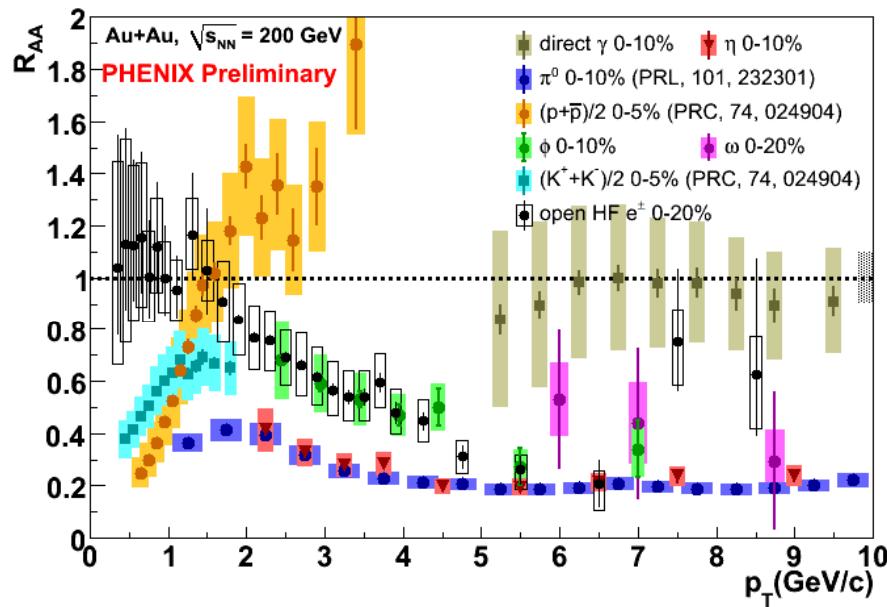
- At forward rapidity  $\rho+\omega$  more suppressed than  $\phi$  and  $J/\psi$

# Rcp ratios $(\rho+\omega)/\phi$



- Systematic uncertainties due to  $N_{coll}$ , trigger efficiency correction, and reconstruction efficiency correction, are cancelled
- Quark flavor dependence observed in suppression at forward rapidity

# Conclusions



- Comprehensive study of  $\phi$  meson production and nuclear modification
- Similar  $R_{AA}$ ,  $R_{CP}$  for strange and heavy quarks observed at mid-rapidity and in forward rapidity (dAu) although the production and suppression mechanisms must be different
- Stronger suppression for light-quark hadrons
- Elliptic flow  $p_T$  reach is extended with Run 7 data. New Run 10 data has more than doubled the data set.
- Stay tuned for more precision results on identified particle production and flow !



